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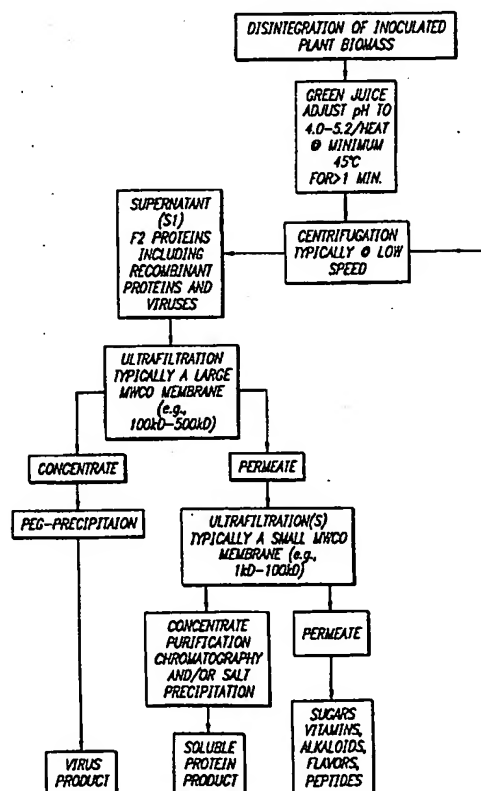
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(54) Title: A PROCESS FOR ISOLATING AND PURIFYING VIRUSES, SOLUBLE PROTEINS AND PEPTIDES FROM PLANT SOURCES

(57) Abstract

The present invention features a method for isolating and purifying viruses, proteins and peptides of interest from a plant host which is applicable on a large scale. Moreover, the present invention provides a more efficient method for isolating viruses, proteins and peptides of interest than those methods described in the prior art. In general, the present method of isolating viruses, proteins and peptides of interest comprises the steps of homogenizing a plant to produce a green juice, adjusting the pH of and heating the green juice, separating the target species, either virus or protein/peptide, from other components of the green juice by one or more cycles of centrifugation, resuspension, and ultrafiltration, and finally purifying virus particles by such procedure as PEG-precipitation or purifying proteins and peptides by such procedures as chromatography and/or salt precipitation.



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A PROCESS FOR ISOLATING AND PURIFYING VIRUSES, SOLUBLE PROTEINS AND PEPTIDES FROM PLANT SOURCES

FIELD OF THE INVENTION

The present invention relates to a process for isolating and purifying viruses, soluble proteins and peptides produced in plants. More specifically, the present invention is applicable on a large scale.

BACKGROUND OF THE INVENTION

Plant proteins and enzymes have long been exploited for many purposes, from viable food sources to biocatalytic reagents, or therapeutic agents. During the past decade, the development of transgenic and transfected plants and improvement in genetic analysis have brought renewed scientific significance and economical incentives to these applications. The concepts of molecular plant breeding and molecular plant farming, wherein a plant system is used as a bioreactor to produce recombinant bioactive materials, have received great attention.

Many examples in the literature have demonstrated the utilization of plants or cultured plant cells to produce active mammalian proteins, enzymes, vaccines, antibodies, peptides, and other bioactive species. Ma *et al.* (*Science* **268**:716-719 (1995)) were the first to describe the production of a functional secretory immunoglobulin in transgenic tobacco. Genes encoding the heavy and light chains of murine antibody, a murine joining chain, and a rabbit secretory component were introduced into separate transgenic plants. Through cross-pollination, plants were obtained to co-express all components and produce a functionally active secretory antibody. In another study, a method for producing antiviral vaccines by expressing a viral protein in transgenic plants was described (Mason *et al.*, *Proc. Natl. Acad. Sci. USA* **93**: 5335-5340 (1996)). The capsid protein of Norwalk virus, a virus causing epidemic acute gastroenteritis in humans was shown to self-assemble into virus-like particles when expressed in transgenic tobacco and potato. Both purified virus-like particles and transgenic potato tubers when fed to mice stimulated the production of antibodies against the Norwalk virus capsid protein. Alternatively, the production and purification of a vaccine may be facilitated by engineering a plant virus that carries a mammalian pathogen epitope. By using a plant virus, the accidental shedding of virulent virus with the vaccine is abolished, and the same plant virus may be used to vaccinate several hosts. For example, malarial epitopes have been presented on the surface of recombinant tobacco mosaic virus (TMV) (Turpen *et al.* *BioTechnology* **13**:53-57 (1995)). Selected B-cell epitopes were either inserted into the

surface loop region of the TMV coat protein or fused into the C terminus. Tobacco plants after infection contain high titers of the recombinant virus, which may be developed as vaccine subunits and readily scaled up. In another study aimed at improving the nutritional status of pasture legumes, a sulfur-rich seed albumin from sunflower was expressed in the leaves of transgenic subterranean clover (Khan *et al. Transgenic Res.* 5:178-185 (1996)). By targeting the recombinant protein to the endoplasmic reticulum of the transgenic plant leaf cells, an accumulation of transgenic sunflower seed albumin up to 1.3 % of the total extractable protein could be achieved.

Work has also been conducted in the area of developing suitable vectors for expressing foreign genetic material in plant hosts. Ahlquist, U.S. Patent 4,885,248 and U.S. Patent 5,173,410 describe preliminary work done in devising transfer vectors which might be useful in transferring foreign genetic material into plant host cells for the purpose of expression therein. Additional aspects of hybrid RNA viruses and RNA transformation vectors are described by Ahlquist *et al.* in U.S. Patents 5,466,788, 5,602,242, 5,627,060 and 5,500,360 all of which are herein incorporated by reference. Donson *et al.*, U.S. Patent 5,316,931 and U.S. Patent 5,589,367, herein incorporated by reference, demonstrate for the first time plant viral vectors suitable for the systemic expression of foreign genetic material in plants. Donson *et al.* describe plant viral vectors having heterologous subgenomic promoters for the systemic expression of foreign genes. The availability of such recombinant plant viral vectors makes it feasible to produce proteins and peptides of interest recombinantly in plant hosts.

Elaborate methods of plant genetics are being developed at a rapid rate and hold the promise of allowing the transformation of virtually every plant species and the expression of a large variety of genes. However, in order for plant-based molecular breeding and farming to gain widespread acceptance in commercial areas, it is necessary to develop a cost-effective and large-scale purification system for the bioactive species produced in the plants, either proteins or peptides, especially recombinant proteins or peptides, or virus particles, especially genetically engineered viruses.

Some processes for isolating proteins, peptides and viruses from plants have been described in the literature (Johal, U.S. Patent, 4,400,471, Johal, U.S. Patent, 4,334,024, Wildman *et al.*, U.S. Patent 4,268,632, Wildman *et al.*, U.S. Patent 4,289,147, Wildman *et al.*, U.S. Patent 4,347,324, Hollo *et al.*, U.S. Patent 3,637,396, Koch, U.S. Patent 4,233,210, and Koch, U.S. Patent 4,250,197, the disclosure of which are herein incorporated by reference). The succulent leaves of plants, such as tobacco, spinach, soybean, and alfalfa, are typically composed of 10-20% solids, the remaining fraction

being water. The solid portion is composed of a water soluble and a water insoluble portion, the latter being predominantly composed of the fibrous structural material of the leaf. The water soluble portion includes compounds of relatively low molecular weight (MW), such as sugars, vitamins, alkaloids, flavors, amino acids, and other compounds of relatively high MW, such as native and recombinant proteins.

Proteins in the soluble portion of plant biomass can be further divided into two fractions. One fraction comprises predominantly a photosynthetic protein, ribulose 1,5-diphosphate carboxylase (or RuBisCO), whose subunit molecular weight is about 550 kD. This fraction is commonly referred to as "Fraction 1 protein." RuBisCO is abundant, comprising up to 25% of the total protein content of a leaf and up to 10% of the solid matter of a leaf. The other fraction contains a mixture of proteins and peptides whose subunit molecular weights typically range from about 3 kD to 100 kD and other compounds including sugars, vitamins, alkaloids, flavors, amino acids. This fraction is collectively referred to as "Fraction 2 proteins." Fraction 2 proteins can be native host materials or recombinant materials including proteins and peptides produced via transfection or transgenic transformation. Transfected plants may also contain virus particles having a molecular size greater than 1,000 kD.

The basic process for isolating plant proteins generally begins with disintegrating leaf biomass and pressing the resulting pulp to produce "green juice". The process is typically performed in the presence of a reducing agent or antioxidant to suppress unwanted oxidation. The green juice, which contains various protein components and finely particulate green pigmented material, is pH adjusted and heated. The typical pH range for the green juice after adjustment is between 5.3 and 6.0. This range has been optimized for the isolation of Fraction 1 protein (or ribulose 1,5-diphosphate carboxylase). Heating, which causes the coagulation of green pigmented material, is typically controlled near 50 °C. The coagulated green pigmented material can then be removed by moderate centrifugation to yield "brown juice." The brown juice is subsequently cooled and stored at a temperature at or below room temperature. After an extended period of time, e.g. 24 hours, ribulose 1,5-diphosphate carboxylase is crystallized from the brown juice. The crystallized Fraction 1 protein can subsequently be separated from the liquid by centrifugation. Fraction 2 proteins remain in the liquid, and they can be purified upon further acidification to a pH near 4.5. Alternatively, the crystal formation of ribulose 1,5-diphosphate carboxylase from brown juice can be effected by adding sufficient quantities of polyethylene glycol (PEG) in lieu of cooling.

The basic process for isolating virus particles is described in Gooding *et al.* (*Phytopathological Notes* 57:1285 (1967), the teaching of which are herein incorporated by reference). To purify Tobacco Mosaic Virus (TMV) from plant sources in large quantities, infected leaves are homogenized and n-butanol is then added. The mixture is then centrifuged, and the virus is retained in the supernatant. Polyethylene glycol (PEG) is then added to the supernatant followed by centrifugation. The virus can be recovered from the resultant PEG pellet. The virus can be further purified by another cycle of resuspension, centrifugation and PEG-precipitation.

Existing protocols for isolating and purifying plant viruses and soluble proteins and peptides, however, present many problems. First, protein isolation from plant sources have been designed in large part for the recovery of Fraction 1 protein, not for other biologically active soluble protein components. The prior processes for large-scale extraction of F1 proteins was for production of protein as an additive to animal feed or other nutritional substances. Acid-precipitation to obtain Fraction 2 proteins in the prior art is not effective, since most proteins denature in the pellet form. This is especially troublesome for isolating proteins and peptides produced by recombinant nucleic acid technology, as they may be more sensitive to being denatured upon acid-precipitation. Second, the existing methods of separation rely upon the use of solvents, such as n-butanol, chloroform, or carbon tetrachloride to eliminate chloroplast membrane fragments, pigments and other host related materials. Although useful and effective for small-scale virus purification, using solvents in a large-scale purification is problematic. Such problems as solvent disposal, special equipment designs compatible with flammable liquids, facility venting, and worker exposure protection and monitoring are frequently encountered. There are non-solvent based, small-scale virus purification methods, but these are not practical for large scale commercial operations due to equipment and processing limitations and final product purity (Brakke *Adv. Virus Res.* 7:193-224 (1960) and Brakke *et al. Virology* 39: 516-533(1969)). Finally, the existing protocols do not allow a streamline operation such that the isolation and purification of different viruses, proteins and peptides can be achieved with minimum modification of a general purification procedure.

There is a need in the art for an efficient, non-denaturing and solvent-limited large-scale method for virus and soluble protein isolation and purification. This need is especially apparent in cases where proteins and peptides produced recombinantly in plant hosts are to be isolated. The properties of these proteins and peptides are frequently different from those of the native plant proteins. Prior art protocols are not suitable to

isolate recombinant proteins and peptides of interest. In addition, the vast diversity of recombinant proteins and peptides from plants and the stringent purity requirement for these proteins and peptides in industrial and medical application requires an efficient and economical procedure for isolating and purifying them. Efficient virus isolation is also of great importance because of the utility of viruses as transfection vectors and vaccines. In some situations, proteins and peptides of interest may be attached to a virus or integrated with native viral proteins (fusion protein), such that isolating the protein or peptide of interest may in fact comprise isolating the virus itself.

SUMMARY OF THE INVENTION

The present invention features a method for isolating and purifying viruses, proteins and peptides of interest from a plant host which is applicable on a large scale. Moreover, the present invention provides a more efficient method for isolating viruses, proteins and peptides of interest than those methods described in the prior art.

In general, the present method of isolating viruses, proteins and peptides of interest comprises the steps of homogenizing a plant to produce a green juice, adjusting the pH of and heating the green juice, separating the target species, either virus or protein/peptide, from other components of the green juice by one or more cycles of centrifugation, resuspension, and ultrafiltration, and finally purifying virus particles by such procedure as PEG-precipitation or purifying proteins and peptides by such procedures as chromatography, including affinity-based methods, and/or salt precipitation.

In one embodiment, the green juice is pH adjusted to a value of between about 4.0 and 5.2 and heated at a temperature of between about 45-50 °C for a minimum of about one min. This mixture is then subjected to centrifugation. The supernatant produced thereby contains virus if transfected and Fraction 2 proteins including recombinant products. Fraction 2 proteins may be separated from the pelleted Fraction 1 protein and other host materials by moderate centrifugation. Virus particles and Fraction 2 proteins may then be further purified by a series of ultrafiltration, chromatography, salt precipitation, and other methods, including affinity separation protocols, which are well known in the art. One of the major advantages of the instant invention is that it allows Fraction 2 proteins to be subjected to ultrafiltration whereas prior methods do not.

In a second embodiment, after pH and heat treatment, the pellet from centrifugation containing the virus, Fraction 1 protein and other host materials is resuspended in a water or buffer solution and adjusted to a pH of about 5.0-8.0. The

mixture is subjected to a second centrifugation. The resuspension allows the majority of virus to remain in the supernatant after the second centrifugation and Fraction 1 protein and other host materials may be found in the resulting pellet. The virus particles may be further purified by PEG-precipitation or ultrafiltration if necessary prior to PEG-precipitation.

In a third embodiment, the coat protein of a virus is a fusion protein, wherein the recombinant protein or peptide of interest is integrated with the coat protein of a virus. During virus replication or during the process of virus isolation and purification, its coat protein may become detached from the virus genome itself, or accumulate as unassembled virus coat protein or the coat fusion may never be incorporated. After centrifugation of the pH adjusted and heated green juice, the pellet may contain the virus, unassembled fusion proteins, Fraction 1 protein, and other host materials. The pellet is then resuspended in water or a buffer solution and adjusted to a pH about 2.0-4.0 followed by a second centrifugation. The protein will remain in the resulting supernatant. The unassembled protein may be further purified according to conventional methods including ultrafiltration, salt precipitation, affinity separation and chromatography. The peptide or protein of interest may be obtained by chemical cleavage of the fusion protein. Such procedures are well known to those skilled in the art.

In a fourth embodiment, sugars, vitamins, alkaloids, flavors, and amino acids from a plant may also be conveniently isolated and purified. After centrifugation of the pH adjusted and heated green juice, the supernatant contains the Fraction 2 proteins, viruses and other materials, such as sugars, vitamins, alkaloids, and flavors. The supernatant produced thereby may be separated from the pelleted Fraction 1 protein and other host materials by moderate centrifugation. Sugars, vitamins, alkaloids, and flavors may then be further purified by a series of methods including ultrafiltration and other methods, which are well known in the art.

In a fifth embodiment, the present invention features viruses, proteins, peptides, sugars, vitamins, alkaloids, and flavors of interest obtained by the procedures described herein.

BRIEF DESCRIPTION OF THE FIGURE

Figure 1 represents a flow chart which demonstrates the present method for isolating and purifying viruses and soluble proteins and peptides from plant sources.

DETAILED DESCRIPTION OF THE INVENTION

The present invention features a novel method for isolating and purifying viruses, proteins and peptides of interest from a plant host. Moreover, the present invention provides a more efficient method for isolating viruses, proteins and peptides of interest than those methods described in the prior art. In addition, the present method is applicable on a large production scale.

In general, the present method of isolating viruses, proteins and peptides of interest comprises the steps of homogenizing a plant to produce a green juice, adjusting the pH of and heating the green juice, separating the target species, either virus or protein/peptide, from other components of the green juice by one or more cycles of centrifugation, resuspension, and ultrafiltration, and finally purifying virus particles by such procedure as PEG-precipitation or purifying proteins and peptides by such procedures as chromatography, including affinity separation, and/or salt precipitation.

An illustration of the instant invention is presented in Figure 1. However, this figure is intended merely to visualize the present invention and is not to be construed as being limiting to the procedures or orders of their appearances depicted therein. Any modifications of the instant invention which are functionally equivalent to the procedures and conditions disclosed herein are within the scope of the instant invention.

The initial step of the present method features homogenizing the subject plant. Plant leaves may be disintegrated using any appropriate machinery or process available. For instance, a Waring blender for a small scale or a Reitz disintegrator for a large scale has been successfully used in some embodiments of the instant invention. The homogenized mixture may then be pressed using any appropriate machinery or process available. For example, a screw press for a large scale or a cheesecloth for a small scale has been successfully employed in some embodiments of the instant invention. The homogenizing step may be performed in the presence of a suitable reducing agent or oxidizing agent to suppress unwanted oxidation. Sodium metabisulfite ($\text{Na}_2\text{S}_2\text{O}_5$) is successfully used in some embodiments of the instant invention. The subsequent steps to isolate and purify viruses and soluble proteins/peptides may be performed generally according to the following procedures.

pH Adjustment and Heat Treatment of Green Juice

According to the present invention, the pH of the initial green juice is adjusted to a value less than or equal to 5.2 and then heated at a minimum temperature of about 45 °C. In preferred embodiments of the instant invention, the green juice is pH adjusted to

between about 4.0 and 5.2 and is then heated to a temperature of between about 45-50 °C for a minimum of one minute. In some embodiments of the instant invention, heat treatment between 10 to 15 minutes has been used successfully. Those skilled in the art will readily appreciate that the time allocated for heat treatment will vary depending on the recovery of the desired species. Therefore, following pH adjustment, the heating time may vary from about one minute to over 15 minutes. Heat may be applied in any suitable manner, and the invention is not intended to be limiting in this regard. Those skilled in the art will appreciate that pH may be adjusted using many suitable acids or bases well known in the art. In some embodiments of the present invention, phosphoric acid has proven effective. The pH of green juice influences the distribution of virus, proteins and peptides in the supernatant or pellet during subsequent centrifugations. An optimal value for the target species may be obtained by testing the isolation and purification of the virus and or protein or peptide of interest on a small scale. Methods previously described in the literature for non-virus purification adjust the pH of the green juice to a value between 5.3 and 6.0 and use heat treatment of at a temperature of about 48-52 °C.

The heat-treated and pH adjusted green juice is quite unique in that the pH of green juice influences the distribution of virus, proteins and peptides in the supernatant or pellet during subsequent centrifugations. Depending on the species of interest, the pH of green juice may be readily controlled to facilitate the isolation and purification of the desirable product, either virus particles or proteins and peptides. It thus provides a streamlined operation such that the isolation and purification of different viruses and proteins and peptides can be optimized with small modifications of a general purification procedure. Such modifications are within the routine skill of skilled artisans and do not require undue experimentation. The unique characteristic of green juice has enabled it to be processed in a variety of purification steps described below.

Centrifugation of Green Juice

The pH- and heat-treated green juice may then be subjected to centrifugation. Those of skill in the art may readily determine suitable conditions for centrifugation, including time interval and G-force. It is generally contemplated that centrifugation should be of sufficient G-force and time to pellet substantially all of Fraction 1 protein, chloroplast and other host materials, while retaining the desired target species in the supernatant fraction or at a sufficient speed and time to pellet the target species with Fraction 1 protein, chloroplast and other host materials. For example, centrifugation at 3000 x G for two minutes or at 6000 x G for three minutes have been effectively applied

to the green juice in some embodiments of the instant invention. According to the present invention, a majority of Fraction 1 protein, unassembled fusion proteins and peptides, chloroplast and other host materials are pelleted (P1) by centrifugation, while Fraction 2 proteins including recombinant proteins and peptides may generally remain in the supernatant (S1) after this centrifugation (see Figure 1). The virus, however, may partition between pellet and supernatant after centrifugation, depending upon the pH of the green juice the virus species, virus nucleic acid construct, plant species, plant age, and source of plant tissue, among other factors. At a low pH, preferably below a pH of about 5.0, the virus is predominantly retained in the pellet (P1). At a pH of between about 5.0 and 5.2, virus is present in the supernatant (S1) as well. Depending on the species of interest, the pH of green juice and subsequent centrifugation conditions may be readily controlled to facilitate the isolation and purification of the desirable product, either virus particles or proteins and peptides. Thus, the instant process provides a streamlined operation such that the isolation and purification of different viruses and proteins and peptides can be achieved with small modifications of a general purification procedure, which modifications require no undue experimentation for those of ordinary skill in the art.

Resuspension of Pellet in a pH Controlled Buffer

The pellet obtained by centrifugation of the pH-adjusted and heated green juice typically contains Fraction 1 protein, unassembled fusion proteins and peptides, viruses, and other host materials. It may be resuspended in water or in a buffer solution having the desired pH range, or pH adjusted to that range. The optimal pH is determined by the final species of interest. In some preferred embodiments, the pH range of resuspension is about 5.0 to 8.0 for isolating and purifying virus particles (see Figure 1). In other embodiments, the pH range of resuspension is about 2.0 to 4.0 if the desired product is a fusion protein/peptide (see Figure 1). Those skilled in the art may readily choose appropriate buffer solution or acids or bases to reach the designed pH range without undue experimentation. Depending upon the percentage of solids of the pellet formed as a result of the first centrifugation procedure, a resuspension volume can be adjusted to a fraction of the starting green juice volume, typically in amounts of 10 to 100-fold of the original green juice volume.

Isolation and Purification of Virus

Viruses can be recovered from either the pellet (P1) alone, the supernatant (S1), or both the supernatant (S1) and pellet (P1) after centrifugation of the green juice depending upon the pH and degree of virus partitioning.

When the pH of green juice is adjusted to a low value, for example, about 4.0, the virus is in general quantitatively retained in the pellet along with Fraction 1 protein, chloroplast and other host material after centrifugation of the green juice (see Figure 1). After resuspension in a solution having a pH of about 5.0 to 8.0, the mixture may be subjected to another centrifugation step. Virus particles are predominantly retained in the supernatant (S2) and may be separated from Fraction 1 protein, chloroplast fragments and other host materials in the pellets. Usually only about 5-10 % of the starting green juice protein remains in S2. The virus containing supernatant may then be ultrafiltered, if necessary, using a molecular weight cut-off (MWCO) in the range of about 1-500 kD membrane according to any one of the ultrafiltration techniques known to those of skill in the art. For example, a 100 kD MWCO membrane has been successfully used in some embodiments of the instant invention to retain virus particles in the concentrates, while smaller protein components filter through. The ultrafiltration step results in a substantial further reduction in the process volume. In some embodiments, further reductions in the process volume of 1- to 30- fold or greater are attainable. From ultrafiltration or centrifugation, a final purification of virus may be accomplished by prior art methods such as PEG-precipitation, centrifugation, resuspension, and clarification.

In some embodiments of the instant invention, virus particles may also be obtained from the supernatant (S1) after the centrifugation of the green juice. This supernatant fraction normally contains Fraction 2 proteins and peptides (see Figure 1). In some embodiments of the instant invention, the pH of green juice may be adjusted to a value between about 5.0 and 5.2, preferably around pH 5.0. A significant portion of virus particles may then be recovered from the supernatant (S1) in addition to the pellet (P1) after centrifugation of the green juice. The virus containing supernatant may be ultrafiltered including, if necessary, diafiltration using a molecular weight cut-off membrane in the range of about 1-500 kD according to any one of the ultrafiltration and diafiltration techniques known to those skilled in the art. For example, a 100 kD MWCO membrane has been successfully used in some embodiments of the instant invention to retain virus particles in the concentrates, while smaller protein components, e.g. Fraction 2 proteins filter through. The ultrafiltration step results in a substantial further reduction in the process volume. From ultrafiltration or centrifugation, a final purification of virus

may be accomplished by prior art methods such as PEG-precipitation, centrifugation, resuspension, and clarification.

An isolation and purification procedure according to the methods described herein has been used to isolate TMV-based viruses from three tobacco varieties (Ky8959, Tn86 and MD609) and *Nicotiana benthamiana*. A number of TMV-based viruses have been obtained Figure including, TMV204 (wild type, SEQ ID NO:1:), TMV261 (coat protein read-throughs, SEQ ID NO:2:), TMV291 (coat protein loop fusion, SEQ ID NO:3:), TMV811 (SEQ ID NO:4:), and TMV861 (coat protein read-throughs, SEQ ID NO:5:). TMV 261 and TMV291 have been shown to be unstable during some isolation procedures, yet remain intact during the present procedure. These viral vectors are used merely as examples of viruses that can be recovered by the instant invention and are not intended to limit the scope of the invention. A person of ordinary skill in the art will be able to use the instant invention to recover other viruses. The virus of interest may be a potyvirus, a tobamovirus, a bromovirus, a carmovirus, a luteovirus, a marafivirus, the MCDV group, a necrovirus, the PYFV group, a sobemovirus, a tombusvirus, a tymovirus, a capillovirus, a closterovirus, a carlavirus, a potexvirus, a comovirus, a dianthovirus, a fabavirus, a nepovirus, a PEMV, a furovirus, a tobravirus, an AMV, a tenuivirus, a rice necrosis virus, caulimovirus, a geminivirus, a reovirus, the commelina yellow mottle virus group and a cryptovirus, a Rhabovirus, or a Bunyavirus.

The present methods of isolating and purifying virus particles represent significant advantages over the prior art methods. They allow the ultrafiltration of virus-containing supernatant (S1 and/or S2), which significantly reduces the processing volume and removes plant components, such as, sugars, alkaloids, flavors, and pigments and Fraction 1 and 2 proteins. Desired virus particles can be enriched as particulate. The concentration and purification of virus particles is thus rapid and effective.

Isolation and Purification of Soluble Proteins and Peptides

The Fraction 2 proteins including recombinant proteins and peptides remain soluble after pH adjustment and heat treatment and centrifugation of green juice (see Figure 1). The Fraction 2 protein-containing supernatant has removed sufficient Fraction 1 proteins, chloroplast and other host materials, to enable an efficient isolation and purification of Fraction 2 proteins, especially recombinant proteins and peptides, using size fractionation by ultrafiltration, concentration and diafiltration. Ultrafiltration is typically performed using a MWCO membrane in the range of about 1 to 500 kD according to methods well known in the art. In some embodiments of the instant

invention, a large MWCO membrane is first used to filter out the residual virus and other host materials. Large molecular weight components may remain in the concentrates. Filtrates containing the proteins/peptides of interest may be optionally passed through another ultrafiltration membrane, typically of a smaller MWCO, such that the target compound can be collected in the concentrates. Additional cycles of ultrafiltration may be conducted, if necessary, to improve the purity of the target compound. The choice of MWCO size and ultrafiltration conditions depends on the size of the target compound and is an obvious variation to those skilled in the art. The ultrafiltration step generally results in a reduction in process volume of about 10- to 30- fold or more and allows diafiltration to further remove undesired molecular species. Finally, proteins or peptides of interest may be purified using standard procedures such as chromatography, salt precipitation, solvent extractions including super critical fluids such as CO₂ and other methods known to those of skill in the art.

The present isolation procedure has been used to successfully isolate and concentrate secretory IgA antibody and α -trichosanthin. The invention is also specifically intended to encompass embodiments wherein the peptide or protein of interest is selected from the group consisting of IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, EPO, G-CSF, GM-CSF, hPG-CSF, M-CSF, Factor VIII, Factor IX, tPA, receptors, receptor antagonists, antibodies, single-chain antibodies, enzymes, neuropolypeptides, insulin, antigens, vaccines, peptide hormones, calcitonin, and human growth hormone. In yet other embodiments, the soluble protein or peptide of interest may be an antimicrobial peptide or protein consisting of protegrins, magainins, cecropins, melittins, indolicidins, defensins, β -defensins, cryptidins, clavainins, plant defensins, nicin and batenecins. These and other proteins and peptides of interest may be naturally produced or produced by recombinant methodologies in a plant.

The present method of isolating and purifying Fraction 2 proteins represents significant advantages from the prior art methods. First, it does not require acid-precipitation of F2 proteins. Acid-precipitation in the prior art may not be desired since many proteins may be denatured or lose enzymatic or biological activity. Fraction 2 proteins including recombinant proteins and peptides in the instant invention are not retained in a pellet form, thereby minimizing the risk of protein denaturation. The present method thereby minimizes denaturation of proteins and peptides of interest. Second, because the more abundant component, Fraction 1 protein, is eliminated during the early stages of purification, the down-stream process allows the ultrafiltration of Fraction 2 proteins. Ultrafiltration of Fraction 2 proteins permits significant reduction of processing

volume and allows rapid concentration and purification of proteins and peptides. Desirable proteins and peptides can be enriched by molecular weight. Rapid concentration and purification also reduces or eliminates the degradation or denaturation due to endogenous protease activities. Ultrafiltration of Fraction 2 proteins is not applicable with methods in the prior art. Finally, the concentration of Fraction 2 proteins including recombinant proteins and peptides requires no solvents and no additional chemicals. Plant protein and peptide isolation procedures in the prior art frequently use solvents such as n-butanol, chloroform, and carbon tetrachloride to eliminate chloroplast membrane fragments, pigments and other host related materials. Such methods are not easily practiced on a large and commercially valuable scale since these methods present the problems of safety and solvent disposal, which often require designing special equipment compatible with flammable fluids, and hence require facility venting and providing protective equipment to workers.

Isolation and Purification of Unassembled Fusion Proteins and Fusion Peptides

During virus replication or during the process of isolating and purifying a virus, its coat protein may become detached from the virus genome itself, or accumulate as unassembled virus coat protein, or the coat protein may never be incorporated. One of ordinary skill in the art can envision that the coat protein can be designed through established recombinant nucleic acid protocols to intentionally be unassembled for commercial recovery of proteins having a plurality of biochemical features. This coat protein may contain a recombinant component integrated with the native coat protein, or fusion proteins. These unassembled fusion proteins typically co-segregate in the pellet (P1) with Fraction 1 protein after centrifugation of pH adjusted and heated green juice (see Figure 1). The pellet may then be resuspended in water or in a buffer with a pH value within the range of about 2.0 to 4.0 followed by another centrifugation. The unassembled protein may be further purified according to conventional methods including a series of ultrafiltration, centrifugation and chromatography steps. The fusion peptide may be obtained followed by chemical cleavage of the desired peptide or protein from the fusion peptide (fusion proteins). Such procedures are well known to those skilled in the art.

The present isolation procedure has been used to successfully isolate and concentrate α -amylase-indolicidin fusion protein. The invention is also specifically intended to encompass embodiments wherein the fusion protein or peptide may contain a peptide or protein selected from the group consisting of IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, EPO, G-CSF, GM-CSF, hPG-CSF, M-CSF, Factor

VIII, Factor IX, tPA, receptors, receptor antagonists, antibodies, single-chain antibodies, enzymes, neuropeptides, insulin, antigens, vaccines, peptide hormones, calcitonin, and human growth hormone. In yet other embodiments, the protein or peptide present in the fusion protein or peptide may be an antimicrobial peptide or protein consisting of protegrins, magainins, cecropins, melittins, indolicidins, defensins, β -defensins, cryptidins, clavainins, plant defensins, nicin and batenecins.

Isolation and Purification of Sugars, Vitamins, Alkaloids, and Flavors

Sugars, vitamins, alkaloids, flavors, amino acids from a plant may also be conveniently isolated and purified using the method of the instant invention. After centrifugation of the pH adjusted and heated green juice, the supernatant contains the Fraction 2 proteins, viruses and other materials, including sugars, vitamins, alkaloids, and flavors. The supernatant produced thereby may be separated from the pelleted Fraction 1 protein and other host materials by centrifugation. Sugars, vitamins, alkaloids, flavors may then be further purified by a series of low molecular weight cutoff ultrafiltration and other methods, which are well known in the art.

Definitions

In order to provide an even clearer and more consistent understanding of the specification and the claims, including the scope given herein to such terms, the following definitions are provided:

A "virus" is defined herein to include the group consisting of a virion wherein said virion comprises an infectious nucleic acid sequence in combination with one or more viral structural proteins; a non-infectious virion wherein said non-infectious virion comprises a non-infectious nucleic acid in combination with one or more viral structural proteins; and aggregates of viral structural proteins wherein there is no nucleic acid sequence present or in combination with said aggregate and wherein said aggregate may include virus-like particles (VLPs). Said viruses may be either naturally occurring or derived from recombinant nucleic acid techniques and include any viral-derived nucleic acids that can be adopted whether by design or selection, for replication in whole plants, plant tissues or plant cells.

A "virus population" is defined herein to include one or more viruses as defined above wherein said virus population consists of a homogenous selection of viruses or wherein said virus population consists of a heterogenous selection comprising any combination and proportion of said viruses.

"Virus-like particles" (VPLs) are defined herein as self-assembling structural proteins wherein said structural proteins are encoded by one or more nucleic acid sequences wherein said nucleic acid sequence(s) is inserted into the genome of a host viral vector.

"Protein and peptides" are defined as being either naturally-occurring proteins and peptides or recombinant proteins and peptides produced via transfection or transgenic transformation.

EXAMPLES

The following examples further illustrate the present invention. These examples are intended merely to be illustrative of the present invention and are not to be construed as being limiting. The examples are intended specifically to illustrate recoveries of virus, protein and peptide of interest which may be attained using the process within the scope of the present invention.

EXAMPLE 1

Fraction 1 Protein Pelleted From Green Juice at Low pH

A tobacco plant of variety MD609 was inoculated 27 days after sowing with TMV 811. Forty days after inoculation, the plant was harvested. Leaf and stalk tissue (150 g) were combined with 0.04% sodium metabisulfite solution (150 ml) in a 1-L Waring blender. The plant tissue was ground on high speed for a period of two minutes. The resulting homogenate was pressed through four layers of cheesecloth, and the pressed fiber was discarded. The volume of juice collected was 240 ml and its pH was 5.57.

With constant stirring, the pH was slowly adjusted downward with dilute phosphoric acid (H_3PO_4). A juice sample (35 ml) was removed at each of the following pH values: pH 5.4, pH 5.3, pH 5.2, pH 5.1, and pH 5.0. Subsequently, all samples were heated to 45°C in a water bath and maintained at this temperature for ten minutes. Samples were then cooled to 25°C in a cold water bath. The cooled samples were centrifuged at 10,000 x G for 15 minutes.

The supernatants (S1 in Figure 1) were decanted and analyzed for Fraction 1 protein level by the Bradford assay and SDS-PAGE. The virus was PEG-precipitated and isolated from a portion of each supernatant (25 ml) by the method of Gooding, *supra*. Virus concentrations were determined by spectrophotometric analysis at 260 nm..

Table 1. Total protein concentrations and virus yields in S1 portion after green juices are adjusted to low pH and heated at 45°C for 10 minutes.

pH of Green Juice	Total Protein Concentration in S1 (mg/ml)	Virus Yield (mg/g of fresh weight)
5.4	4.44	0.22
5.3	3.77	0.21
5.2	2.30	0.22
5.1	1.41	0.23
5.0	0.88	0.20

Results:

The total protein as determined by the method of Bradford retained in the soluble portion (S1) as determined by the method of Bradford after centrifugation is gradually reduced when the pH of the green juice is adjusted downwards from 5.4 to 5.0. In particular, at pH 5.0 of green juice followed by heat-treatment at 45°C for 10 minutes (referred to as "pH 5.0/45°C process"), the amount of Fraction 1 protein left in S1 shows more than a five-fold reduction compared to the pH 5.5/45°C process. More Fraction 1 protein is pelleted at low pH value of green juice. The solubility of virus in S1, however, remains unaffected.

Subsequent examples also demonstrate that while Fraction 1 protein is pelleted at this pH range, the majority of Fraction 2 proteins remains in the supernatant. A conventional method of isolating soluble plant proteins adjusts the pH of green juice within the range of 5.3-6.0, which directs Fraction 1 protein to the supernatant after the centrifugation. The pH adjustment of green juice to a value below 5.2 followed by moderate heating in the instant procedure thus allows the separation of Fraction 1 and Fraction 2 protein upon the centrifugation of green juice. Eliminating the abundant Fraction 1 protein from the soluble portion simplifies the subsequent isolation and purification of Fraction 2 proteins. An ultrafiltration method can now be successfully applied to the purification of Fraction 2 proteins. This is an appreciable advantage over the prior art, where Fraction 1 protein is preferably retained in the soluble portion until the final crystallization or precipitation. Ultrafiltration in the presence of a large amount of Fraction 1 protein and other host materials is not efficient.

EXAMPLE 2Distribution of Virus From Green Juice At Different pH Values

Nicotiana tabacum (KY8959) grown in a greenhouse was inoculated with a TMV derivative (coat protein loop fusion), TMV291, seven weeks post seed germination. Plants were harvested two and half weeks post inoculation after systemic spread of the virus. Leaf and stalk tissue (150 g) was macerated in a 1-liter Waring blender for two minutes at the high setting with 0.04% $\text{Na}_2\text{S}_2\text{O}_5$ (150 ml). The macerated material was strained through four layers of cheesecloth to remove fibrous material. The remaining green juice was adjusted to the pHs of 5.0, 4.8, 4.6, 4.4, 4.2, and 4.0 with H_3PO_4 . Green juice aliquots of 30 ml were removed at each pH for further processing. All pH adjusted green juice samples were heat-treated at 45°C for 15 minutes in a water bath and then cooled to 15°C. Samples were centrifuged in a JS-13.1 rotor at 10,000 RPM for 15 minutes resulting in two fractions, supernatant (S1) and pellet (P1) (see Figure 1). Pellets were resuspended in 15 ml of 50 mM phosphate buffer, pH 7.2 and centrifuged in a JS-13.1 rotor at 10,000 RPM for 15 minutes resulting in two fractions, supernatant (S2) and pellet (P2), see Figure 1. Virus was recovered from both supernatant fractions by PEG-precipitation (8,000 MW PEG) as described by Gooding, *supra* and quantified by spectrophotometric analysis at 260 nm.

Table 2. Distribution of Virus in S1 and S2 at Different Green Juice pHs

pH of Green Juice	Supernatant	Virus (mg)	Ratio of Virus (S2/S1)
5.00	S1	0.400	
5.00	S2	0.482	1.21
4.80	S1	0.200	
4.80	S2	0.570	2.85
4.60	S1	0.107	
4.60	S2	0.486	4.54
4.40	S1	0.016	
4.40	S2	0.696	43.5
4.20	S1	0.010	
4.20	S2	0.859	85.9
4.00	S1	0.006	
4.00	S2	0.799	133.2

Results:

This example examines the relative distribution of virus in supernatant, S1 and S2, during the first and second centrifugation, respectively. S1 is obtained after pH

adjustment of green juice, from 5.0 to 4.0, followed by heat treatment and centrifugation. The pellet (P1) is resuspended in a buffer (pH 7.2) and subsequently subjected to a second centrifugation, which produces supernatant (S2). The amount of virus recovered from S1 and S2 portion is similar at pH 5.0 of green juice in Table 2. Upon lowering the pH, however, virus gradually migrates from the supernatant portion (S1) to the pellet portion (P1) and reappears in S2. At pH 4.0 in Table 2, the amount of virus isolated from S2 portion is more than 100-fold higher than in the S1 portion. The pH of green juice and the pH of the resuspension buffer are shown to have a great effect on the relative distribution of virus in the supernatant or pellet during centrifugation. At a low pH, e.g. pH 4.0/45 °C process and pH 7.2 suspension buffer, the virus can be quantitatively recovered from the S2 portion alone. This process concentrates the virus into one fraction. This results in a fraction that can be ultrafiltered thereby significantly reducing the process volume and overall efficiency of virus purification. Adjusting the pH value of the green juice and suspension buffer offers a method for controlling the distribution of virus and thus facilitates the isolation of virus with large recovery yields.

EXAMPLE 3

Small-Scale Isolation of Virus from S2 Using the pH 4.2/45 °C process

A tobacco plant of variety MD609 was inoculated with TMV 811. Eleven weeks after sowing, the plant was harvested. Leaf and stalk tissue (250 g) were combined with 0.04% sodium metabisulfite solution (250 ml) in a 1-liter Waring blender. The plant tissue was ground on high speed for a period of two minutes. The resulting homogenate was pressed through four layers of cheesecloth and the pressed fiber discarded. The volume of juice collected was 408 ml and its pH was 5.4. With constant stirring, the pH was adjusted to 4.2 with dilute phosphoric acid.

A portion of the juice (285 ml) was heated to 45°C in a water bath and maintained at this temperature for 10 minutes. Without cooling, the juice was centrifuged at 10,000 x G for 15 minutes. The supernatant was decanted and discarded, and the pellet was resuspended in double distilled deionized water (142 ml). The pH of the resuspended pellet was adjusted to pH 8.0 with dilute sodium hydroxide.

The resuspended and pH-adjusted pellet was divided into eight aliquots (15 ml each). These aliquots were centrifuged at different RPMs in a JA-20 rotor in a Beckman J2-21 centrifuge. The second supernatants (S2) were decanted and analyzed by SDS-PAGE. The virus was PEG-precipitated and isolated from the remaining

supernatant (S2) portion according to the method of Gooding, *supra*. Supernatant clarity was also gauged visually.

Table 3. Virus and Protein Yields of S2 under Different Centrifugation Conditions.

Aliquots	RPM	Minutes	Protein Conc. (mg/ml)	Virus Yield (mg/g fresh weight)	Appearance
1	11,500	15	0.82	0.349	Clear
2	1,500	1	2.54	Not Determined	Cloudy green
3	1,500	3	2.12	Not Determined	Cloudy green
4	3,000	1	1.74	Not Determined	Cloudy green
5	3,000	3	1.25	Not Determined	Slightly cloudy
6	6,000	1	1.00	0.364	Slightly cloudy
7	6,000	3	0.93	0.359	Almost clear
8	9,000	3	0.85	0.348	Almost clear

Results:

Example 2 demonstrates that a low pH of green juice and a neutral pH of suspension buffer directs most of virus into the soluble portion of the second centrifugation (S2). Example 3 further tests the optimal condition for the second centrifugation. If the target species is a virus, one prefers that the supernatant S2 contains as little protein as possible. Such a condition can be generally achieved with a high speed centrifugation for a long time interval, as shown in Aliquot 1 in Table 3. Such a condition, although effective, confers a larger cost and a longer process. An optimal condition provides a lower RPM rate for a shorter period of time without greatly compromising the yield and purity is desirable. Although Aliquots 2-5 operate at a much lower centrifugation speed and for a shorter period, the exclusion of protein is, however, poor, as evidenced by a larger soluble protein concentration and a cloudy solution (an indication of large protein content). Aliquots 6-8 leave much protein out of supernatant (an almost clear solution), the amount of virus recovered in the S2 portion is comparable to that of Aliquot 1, but confers only moderate centrifugation speed and shorter time interval comparing to aliquot 1.

Although it can be seen from the instant example that there is no danger of over centrifuging (Aliquot 1), for a cost-effective virus purification process, centrifugation at a moderate speed and reasonable time interval, sufficient to eliminate the interfering

proteins, is preferred. Those skilled in the art can readily determine the optimal condition of centrifugation that is suitable for isolation of virus of interest.

EXAMPLE 4

Effect of Host Components and Suspension Volume on

Virus Recovery from S2 Using the pH 4.2/45°C Process

Nicotiana tabacum MD609 grown in a greenhouse was inoculated with a TMV derivative (coat protein leaky-stop), TMV811, six weeks post seed germination. Plants were harvested five weeks post inoculation after systemic spread of the virus. Leaf and stalk tissue (150 g) was macerated in a 1-liter Waring blender for two minutes at the high setting with 0.04% $\text{Na}_2\text{S}_2\text{O}_5$ (150 ml). The macerated material was strained through four layers of cheesecloth to remove fibrous material. The remaining green juice was adjusted to a pH of 4.2 with H_3PO_4 . The pH-adjusted green juice was heated to 45°C under hot tap water and incubated for 10 minutes in a 45°C water bath. The heat-treated green juice was separated into 30 ml aliquots and then centrifuged in a JS-13.1 rotor at 10,000 RPM for 15 minutes. The pelleted material was adjusted to either 10 or 20% of the starting 30 ml volume by the addition of supernatant and then further adjusted to 1/4, 1/2 or 1 volume of the starting 30 ml volume by the addition of deionized H_2O . The average pellet volume from 30 ml of green juice was 1.7 ml.

All pellets were completely resuspended in the added supernatant and deionized H_2O and then adjusted to a pH of 7.5-7.7 by the addition of NaOH. The resuspended samples were centrifuged in a JS13.1 rotor at 10,000 RPM for 15 minutes. Virus was recovered from the supernatants by PEG-precipitation (8,000 MW PEG) as described by Gooding, *supra*.

Table 4. Virus Yield under Different Resuspension Volume.

Pellet	Pellet Volume (ml)	Supernatant added back (ml)	(Added Supernatant + Pellet)/ Initial Volume	Deionized H_2O added (ml)	Total Resuspension Volume in ml (ratio)	Virus mg/g fresh weight extracted
1	1.7	1.3	10%	4.5	7.5 (1/4)	0.798
2	1.7	1.3	10%	12.0	15.0 (1/2)	0.877
3	1.7	1.3	10%	27.0	30.0 (1)	0.985
4	1.7	4.3	20%	1.5	7.5 (1/4)	0.489
5	1.7	4.3	20%	9.0	15.0 (1/2)	0.836
6	1.7	4.3	20%	24.0	30.0 (1)	0.952

Results:

When pellets are obtained from centrifugation, they are frequently contaminated with residual supernatant, which may or may not affect the subsequent recovery of the target species. In addition, the resuspension volume may also exert an effect on the recovery of target species. This example is designed to test the virus recovery under the condition where a defined volume of supernatant is added back to the pellet and the resuspension volume is systematically varied in order to assess its effect on virus recovery.

Table 4 demonstrates the inverse relationship of resuspension volume to virus yield. When resuspension volume increases from $\frac{1}{4}$ to $\frac{1}{2}$ and $\frac{1}{2}$ to 1 equivalent of the starting volume (30 ml), the recovery of virus is increased (compare 1 through 3 and 4 through 6). Thus, as the percentage of pellet volume increases, the resuspension volume should also increase to maximize the recovery of virus. For the effect of residual supernatant, the yield of virus recovery is higher when less supernatant is added back to the pellet (compare 1 and 4, 2 and 5, 3 and 6). Host component(s) in the supernatant may affect the ability to resuspend/dissociate virions from the pellet. Thus, a smaller pellet volume with less residual supernatant after centrifugation is desirable. In summary, factors such as the resuspension volume and dryness of the pellet may be optimized to maximize the yield and purity of target species.

EXAMPLE 5Effect of Feed Rate on Large Scale Virus Isolation Using pH 5.0/47°C Process

Field grown tobacco of variety KY8959 was inoculated with TMV 291 and harvested ten weeks after setting. The plant tissue (8,093 lbs.) was ground in a Reitz® disintegrator and the fiber removed using a screw press. Water was added to the disintegrator at the rate of 120 gallons per ton of tobacco. The juice from the press was collected in a stirred tank where the pH was adjusted to 5.0 with phosphoric acid. The pH-adjusted juice was pumped through a heat exchanger in a continuous manner so that the temperature of the juice reached 47°C. The heated juice was then pumped through holding tubes, which ensures that this temperature was maintained for at least ten minutes.

The treated juice was then fed to a Westfalia® SAMR 15037 disk stack-type centrifuge at a feed rate of five gallons per minute to twenty gallons per minute. Samples of the concentrate were taken at each feed rate and analyzed for virus concentration.

Table 5. Virus Yield Versus Feed Rate.

Sample	Feed Rate (GPM)	Virus Conc. (mg/ml)
1	5	2.05
2	10	3.40
3	15	4.03
4	20	4.23

Results:

The virus recovery yield was examined using different feed rates. Table 5 shows that virus recovery was lowered with a low feed rate of green juice to the centrifuge. Since the feed rate is inversely proportional to the retention time of green juice in the centrifuge, these data demonstrate virus is lost if it is subjected to too much centrifugation (low feed rate). Thus, feed rate may also be optimized to maximize the yield and purity of target species in a large scale isolation and purification.

EXAMPLE 6**Isolation of Recombinant Protein α -Trichosanthin Using the pH5.0/45°C Process**

Nicotiana benthamiana grown in a greenhouse was inoculated with TMV containing the gene coding for α -trichosanthin. Plants were harvested ten days post inoculation after systemic spread of the virus. Leaf and stalk tissue (150 g) was macerated in a 1-liter Waring blender for two minutes at the high setting with 0.04% $\text{Na}_2\text{S}_2\text{O}_5$ (150 ml). The macerated material was strained through four layers of cheesecloth to remove fibrous material. The remaining green juice was adjusted to pH 5.0 with HCl. The pH adjusted green juice was heat-treated at 45°C for ten minutes in a water bath and then cooled to 28°C. Heat treated juice was centrifuged in a KA-12 rotor (KompSpin, Sunnyvale, CA) at 10,000 RPM (15,600 x G) for 15 minutes. The supernatant (S1) (50 ml aliquots) was subjected to ultrafiltration using 100 and 10 kD MWCO regenerated cellulose membranes in an Amicon[®] stirred-cell at 50 PSI. The 100 kD permeate fraction was then concentrated via filtration through a 10 kD membrane and diafiltered three times. The α -trichosanthin is collected from the 10 kD concentrate. The 10 kD permeate contains the sugars, alkaloids, flavors, vitamins and peptides below 10 kD MW. The relative quantity of α -trichosanthin in green juice, supernatant, 100 kD and 10 kD concentrates and the 100 to 10 kD fraction was determined by Western analysis using α -trichosanthin antibody.

Table 6. α -trichosanthin Yield in a pH 5.0/45 °C process.

Fraction	Mg Total Protein as Determined by Bradford Analysis	Percentage of α -trichosanthin Recovered Relative to Green Juice Based Upon Western Analysis
Green juice	134	100
S1	22	100
100 kD Concentrate	28.5	96
100 kD Concentrate	16.3	40.8
10 kD Permeate	5.7	Not Determined
100-10 kD Fraction	5.4	34

Results:

This example demonstrates the ability to extract and purify a soluble F2 protein, α -trichosanthin, using the pH 5.0/45°C process and ultrafiltration. The α -trichosanthin was quantitatively retained in the supernatant (S1) fraction, relative to amounts present in the green juice, (based upon Western analysis). In addition, α -trichosanthin present in the S1 was purified 6-fold relative to green juice (based on Bradford protein and Western analysis).

α -Trichosanthin present in the S1 fraction was quantitatively retained and concentrated 4-fold, by ultrafiltration using a 10 kD MWCO membrane (50 ml of S1 was concentrated to 13.5 ml and 96% of the α -trichosanthin was present in the 10 kD concentrate, based upon Western analysis).

α -Trichosanthin was also purified away from large molecular weight proteins and viruses via ultrafiltration with a 100 kD MWCO membrane. The 100 kD concentrate fraction was diafiltered three times to allow recovery of additional α -Trichosanthin. After 100 kD concentration and diafiltration, only 40.8% of the α -Trichosanthin remained in the 100 kD concentrate, indicating that 59.2% of the α -Trichosanthin would be present in the 100 kD permeate fraction. The 100 kD permeate fraction was concentrated using a 10kD MWCO membrane. The resultant 10 kD concentrate (derived from the 100 kD permeate), contained 34% of α -Trichosanthin, relative to the amount of α -Trichosanthin present in 50 ml of the starting S1 fraction. The α -trichosanthin present in the 100-10kD fraction was determined to be purified 8-fold relative to Green juice (based on Bradford

protein and Western analysis) and concentrated 12.5-fold (50 ml of S1 was concentrated to 4.0 ml of 100-10 kD fraction).

EXAMPLE 7

Isolation of Secretory IgA Antibody From Transgenic Plants Using the pH5.0/47°C

Process

Leaf and stalk tissue (50 g fresh weight) of greenhouse grown transgenic tobacco, which expresses four secretory IgA (SIgA) protein components, was macerated in a Virtis blender for two minutes at the high setting with 0.04% $\text{Na}_2\text{S}_2\text{O}_5$ (75 ml). The macerated material was strained through four layers of cheesecloth to remove fibrous material. The remaining green juice was adjusted to pH 5.0 with H_3PO_4 . The pH-adjusted green juice was heat-treated at 47°C for ten minutes in a water bath and then cooled to 28°C. Heat treated juice was centrifuged in a JA-13.1 rotor at 3,000 RPM for three minutes. The supernatant fraction was subjected to ultrafiltration using 10 kD MWCO, regenerated cellulose membrane (Amicon®, Centriprep®). The relative quantity of SIgA in green juice, supernatant and the 10 kD concentrate was determined by Western analysis using an antibody reactive with the heavy chain.

Table 7. Secretory IgA and Other Proteins Recovered from the pH 5.0/47°C Process.

Fraction	Mg Total Protein per ml (Bradford)	Percentage of Total Protein Relative to Green Juice	SIgA (ng/mg Fresh Weight)
Green juice	1.78	100	100
Supernatant (S1)	0.25	14	30
10kD Concentrate (12X)	3.10	14	30

Results:

Secretory IgA antibody, recombinantly produced in transgenic plants, was successfully recovered in this example. Following pH adjustment and heat treatment, centrifugation reduced the total protein in the supernatant by 85%. The SIgA in the supernatant was recovered and ultrafiltered resulting in a 12-fold concentration of the total protein and the SIgA components.

EXAMPLE 8Small Scale Isolation of Virus Using pH 5.0/45 °C Process and Ultrafiltration

Field-grown tobacco of variety MD609 and infected with TMV 261 was harvested and frozen at -20°C until use. The frozen tissue was ground in four batches in a 4-liter Waring blender. In each batch, plant tissue (1500 g) was ground for three minutes at high speed in 0.04% sodium metabisulfite solution (1500 ml). The homogenates were strained through four layers of cheesecloth and the juices combined to give a volume of approximately 10 liters.

The pH of the juice was adjusted from a starting value of 5.8 to 5.0 using concentrated phosphoric acid (H_3PO_4). The juice was then heated to 45°C using a stainless steel coil heated by hot tap water. After maintaining the juice at 45°C for ten minutes, it was cooled to 25°C using the coil with chilled water. The heat-treated juice was centrifuged at 12,000 x G for five minutes and the resulting supernatant was decanted through Miracloth®.

This supernatant was processed using a one square foot, 100 kD MWCO regenerated cellulose, spiral ultrafiltration membrane. With an inlet pressure of 50 psi and a recirculation rate of five liters per minute, the supernatant was concentrated to about 5% of the starting volume. The final concentrate was drained from the ultrafiltration apparatus and the system was rinsed with a small volume of water. Samples of the starting supernatant, the final concentrate, the water rinse, and the combined permeate were assayed for protein by Bradford analysis. They were also PEG-precipitated according to the method of Gooding, *supra*, to isolate any virus present. Virus concentrations were determined spectrophotometrically.

Table 8. Protein Concentration and Virus Yield in Supernatant (S1) and Subsequent Ultrafiltration.

Sample	Total Protein (g)	Virus Yield (g)
Supernatant	3.35	1.94
100 kD MWCO Concentrate	2.64	1.64
100 kD MWCO Permeate	0.22	Not Determined
Membrane Rinse	0.38	0.40

Results:

In this example, a small scale virus isolation was successfully carried out. Green juice was pH adjusted to 5.0 and heat-treated followed by centrifugation. The supernatant

containing virus (1.94 g) was passed through a 100 kD MWCO membrane. The virus (1.64 g) was quantitatively recovered from the concentrate. Proteins of smaller size were collected in the permeate. Only a small amount of virus is lost by ultrafiltration using a 100 kD membrane.

EXAMPLE 9

Large Scale Virus Isolation Using pH 4.0/47°C Process

Field grown tobacco of variety KY8959 was inoculated with TMV 291 and harvested ten weeks after setting. The plant tissue (8,382 lbs.) was ground in a Reitz® disintegrator and the fiber removed using a screw press. Water was added to the disintegrator at the rate of 120 gallons per ton of tobacco. The juice from the press was collected in a stirred tank where the pH was adjusted to 4.0 with phosphoric acid. The pH adjusted juice was pumped through a heat exchanger in a continuous manner so that the temperature of the juice reached 47°C. The heated juice was then pumped through holding tubes which ensures that this temperature was maintained for at least ten minutes.

The treated juice was then fed to a Westfalia SAMR 15037 disk stack type centrifuge at a feed rate of 10 gallons per minute. A total of 1120 gallons of supernatant and 200 gallons of pellet were produced during centrifugation. A volume of 380 gallons of water was added to the pellet, and the resuspended pellet pH was adjusted to 7.12 by the addition of KOH. The pH adjusted, resuspended pellet was then fed to a Westfalia SAMR 15037 disk stack type centrifuge at a feed rate of 5 gallons per minute resulting in the recovery of 435 gallons of supernatant (S2). Supernatant (435 gallons) was concentrated to 24.8 gallons by ultrafiltration through 1,000 square feet of 100 kD MWCO, cellulose acetate, spiral membrane (SETEC, Livermore, CA). After removal of the concentrate, the membranes were washed with 31.5 gallons of water. Virus (158 g) was purified from the 100 kD MWCO concentrate and then further concentrated and washed by PEG -precipitation (8,000 MW PEG) as described by Gooding, *supra*. This quantity of virus recovered is two orders of magnitude greater than ever isolated before.

This example demonstrates an efficient large scale virus isolation using the pH4.0/47°C process. Example 2, *supra*, demonstrates that the pH 4.0/47°C process allows the concentration of virus in the supernatant, S2 on a small scale. The virus can be further concentrated using ultrafiltration by passing the supernatant (S2) through a 100 kD MWCO membrane. The virus particles can be recovered at high yield as shown in this example.

EXAMPLE 10Large Scale Virus and Fraction 2 Protein Isolation Using pH 5.0/47°C Process

Field-grown tobacco of variety KY8959 was inoculated with TMV 291 and harvested ten weeks after setting. The plant tissue (8,093 lbs.) was ground in a Reitz® disintegrator and the fiber removed using a screw press. Water was added to the disintegrator at the rate of 120 gallons per ton of tobacco. The juice from the press was collected in a stirred tank where the pH was adjusted to 5.0 with phosphoric acid. The pH-adjusted juice was pumped through a heat exchanger in a continuous manner so that the temperature of the juice reached 47°C. The heated juice was then pumped through holding tubes which ensures that this temperature was maintained for at least 10 minutes.

The treated juice was then fed to a Westfalia® SAMR 15037 disk stack type centrifuge at a feed rate of ten gallons per minute. A total of 760 gallons of the 990 .. gallons of supernatant produced during centrifugation was concentrated to 32 gallons by ultrafiltration through 1,000 square feet of 100 kD MWCO, cellulose acetate, spiral membrane. Virus (213 g) was purified from the 100 kD concentrate fraction by PEG (8,000 MW) precipitation as described by Gooding, *supra*. The soluble Fraction 2 proteins (<100 kD) located in the 100-kD filtration permeate, were concentrated by ultrafiltration through 40 square feet of 10 kD MWCO, regenerated cellulose, spiral membrane. A total of 60 gallons of 100 kD permeate was concentrated to 3.5 gallons, yielding 1.69 g of soluble Fraction 2 proteins.

This example successfully demonstrates that a large-scale process for isolating and purifying Fraction 2 proteins and virus using pH 5.0/47°C process. The first centrifugation produces a supernatant fraction that contains both virus and other soluble proteins. It is possible to use ultrafiltration to concentrate and separate the virus and soluble Fraction 2 proteins, where virus remains in the concentrate of a large MW MWCO membrane and Fraction 2 proteins in the permeate. Fraction 2 proteins can be further purified and concentrated by passing through a smaller MW MWCO membrane, where different sizes of Fraction 2 proteins can be individually obtained. Fraction 2 protein and virus can be recovered with high yields using the instant method at a large scale.

EXAMPLE 11**Physiochemical Properties of the Purified Virus Particles****Produced by the pH5.0/47°C or the pH4.0/47°C Process**

Wild type tobacco mosaic virus (TMV204, sample 960808) was extracted from field grown tobacco (variety KY8959, 11,884 lbs.) using the large-scale pH4.0/47°C process as described in Example 9. Recombinant TMV291 (sample 960829) was extracted from field grown tobacco (variety KY8959, 14,898 lbs.) using the pH5.0/47°C extraction procedure as described in Example 10. The virion, after PEG precipitation, were subjected to various analyses to ascertain biochemical and purity profiles.

Table 9. Virion Purity Profiles after Large Scale Isolation using pH4.0/47°C and pH5.0/47°C Processes.

Analysis	Sample 960808 (pH4.0/47°C process)	Sample 960829 (pH5.0/47°C process)
Absorbance ratio (260/280 nm)	1.194	1.211
*MALDI-TOF (molecular mass)	17,507.3	18,512.5
Moisture in percentage	41.96	54.57
Percentage of Total lipids (Wet weight basis)	2.15	1.30

* Matrix Assisted Laser Desorption Ionization-Time of Flight, Mass Spectrometry.

Table 10. Elemental Analysis of Virions after Large Scale Isolation Using pH4.0/47°C and pH5.0/47°C Processes.

Elemental Analysis (dry weight basis)	Sample 960808 (pH4.0/47°C process)	Sample 960829 (pH5.0/47°C process)
Carbon	45.67%	44.80%
Hydrogen	6.58%	6.48%
Nitrogen	13.87%	13.65%
Oxygen	24.20%	24.16%
Sulfur	0.18%	<0.5%
Nicotine by HPLC	1.44 ppm	5.68 ppm
**Endotoxin EU/ml at 1.0 µg virus/ml	0.2475 ± 0.13	0.1213 ± 0.03

** Endotoxin levels were determined by the Chromogenic Limulus Amebocyte Lysate Test.

Table 11. Amino Acid Analysis of Virions after Large Scale Isolation Using pH4.0/47°C and pH5.0/47°C Processes.

***Amino Acid Analysis μmoles, reported on dry weight basis	Sample 960808 (pH4.0/47°C process)	Sample 960829 (pH5.0/47°C process)
Asp	22.95	26.28
Ser	17.73	16.38
Glu	19.80	18.72
Gly	8.37	12.78
Arg	14.94	18.90
Thr	19.17	19.62
Ala	19.17	21.96
Pro	10.17	9.45
Tyr	4.68	4.14
Val	18.36	18.63
Lys	1.71	2.43
Ile	9.81	10.26
Leu	15.30	15.39
Phe	10.18	10.08

*** Quantity of sample analyzed, wet weight (960808: 537.47 mg, 960829: 554.28 mg).

Results:

The analysis of PEG purified virion preparations produced via the large-scale pH5.0/47°C and pH4.0/47°C processes, indicate a high degree of purity and no detectable TMV coat protein degradation. Absorbance ratios of 1.20 at 260/280 nm (Table 9) are indicative of highly purified TMV. In addition, the MALDI-TOF mass of both virus preparations (Table 9) are within experimental ranges for the predicted coat protein molecular weight. Both virus preparations contained low levels of lipids, nicotine and endotoxin, again demonstrating the utility of these methods in the isolation and purification of virions and virus fusion coat protein. The elemental analyses of the virus extracts (Table 10) are indicative of highly purified proteins as determined by the relative ratios of the various elements. The amino acid profiles of the virus samples (Table 11) reflect the relative abundance of each predicated amino acid and also reflects the predicted differences in amino acids between the two test samples.

Both virus samples were shown to be infective when passed onto host plants, indicating that the described methods resulted in the recovery of biologically active virions. RT-PCR analysis of the virus extracts produced the predicated nucleic acid fragments, indicative of intact RNA genomes.

Although the invention has been described with reference to the presently preferred embodiments, it should be understood that various modifications can be made without departing from the spirit of the invention. Accordingly, the invention is limited only by the following claims.

WE CLAIM:

1. A method for obtaining a soluble protein or peptide of interest from a plant comprising the steps of:
 - (a) homogenizing a plant to produce a green juice;
 - (b) adjusting the pH of the green juice to less than or equal to about 5.2;
 - (c) heating the green juice to a minimum temperature of about 45 °C;
 - (d) centrifuging the green juice to produce a supernatant; and
 - (e) purifying the protein or peptide of interest from the supernatant.
2. The method of claim 1 wherein the pH of the green juice is adjusted to between about 4.0 and 5.2.
3. The method of claim 1 wherein the pH of the green juice is adjusted to about 5.0.
4. The method of claim 1 wherein the green juice is heated to a temperature of between about 45° and 50° C.
5. A method for purifying a protein or peptide of interest according to claim 1 wherein the supernatant produced in step (d) is further subjected to ultrafiltration.
6. A method for purifying a protein or peptide of interest according to claim 5 further comprising the step of subjecting a permeate produced by the said ultrafiltration to a second ultrafiltration.
7. A method for purifying a protein or peptide of interest according to claim 6 further comprising the step of purifying a concentrate resulting from the second ultrafiltration.
8. The method of claim 7 wherein said purifying is performed by chromatography, affinity-based method of purification, or salt precipitation.
9. The method of any one of claims 1 through 8 wherein the soluble protein or peptide of interest is selected from the group consisting of IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, EPO, G-CSF, GM-CSF, hPG-CSF, M-CSF, Factor VIII, Factor IX, tPA, receptors, receptor antagonists, antibodies, single-chain

antibodies, enzymes, neuropolypeptides, insulin, antigens, vaccines, peptide hormones, calcitonin, and human growth hormone.

10. The method of any one of claims 1 through 8 wherein the soluble protein or peptide of interest is an antimicrobial peptide or protein and is selected from the group consisting of protegrins, magainins, cecropins, melittins, indolicidins, defensins, β -defensins, cryptidins, clavainins, plant defensins, nicin and battenecins.

11. The method of any one of claims 1 through 8 wherein the said protein or peptide of interest is produced by recombinant techniques.

12. A method for obtaining a virus of interest from a plant comprising the steps of:

- (a) homogenizing a plant to produce a green juice;
- (b) adjusting the pH of the green juice to less than or equal to about 5.2;
- (c) heating the green juice to a minimum temperature of about 45° C;
- (d) centrifuging the green juice to produce a supernatant; and
- (e) purifying the virus of interest from the supernatant.

13. The method of claim 12 wherein the pH of the green juice is adjusted to between about 4.0 and 5.2.

14. The method of claim 12 wherein the pH of the green juice is adjusted to about 5.0.

15. The method of claim 12 wherein the green juice is heated to a temperature between about 45 and 50 °C.

16. A method for obtaining a virus of interest according to claim 12 further comprising the step of subjecting the supernatant to ultrafiltration.

17. A method for obtaining a virus of interest according to claim 15 further comprising the step of adding polyethylene glycol to a concentrate resulting from the ultrafiltration.

18. The method of any one of claims 12 through 17 wherein the virus of interest is a plus-sense RNA virus.

19. The method of any one of claims 12 through 17 wherein said virus of interest is selected from the group consisting of a potyvirus, a tobamovirus, a bromovirus, a carmovirus, a luteovirus, a marafivirus, the MCDV group, a necrovirus, the PYFV group, a sobemovirus, a tombusvirus, a tymovirus, a capillovirus, a closterovirus, a carlavirus, a potexvirus, a comovirus, a dianthovirus, a fabavirus, a nepovirus, a PEMV, a furovirus, a tobravirus, an AMV, a tenuivirus and a rice necrosis virus.
20. The method of any one of claims 12 through 17 wherein said virus of interest is selected from the group consisting of a caulimovirus, a geminivirus, a reovirus, the commelina yellow mottle virus group and a cryptovirus.
21. The method of any one of claims 12 through 17 wherein said virus of interest is selected from a Rhabovirus and a Bunyavirus.
22. A method for obtaining a virus of interest from a plant comprising the steps of:
- (a) homogenizing a plant to produce a green juice;
 - (b) adjusting the pH of the green juice to less than or equal to about 5.2;
 - (c) heating the green juice to a minimum temperature of about 45°C;
 - (d) centrifuging the green juice to produce a pellet;
 - (e) resuspending the pellet in a liquid solution;
 - (f) adjusting the pH of the liquid solution containing the resuspended pellet to about 5.0 to 8.0;
 - (g) centrifuging the liquid solution containing the resuspended pellet to produce a supernatant; and
 - (h) purifying the virus of interest from the supernatant.
23. A method for obtaining a virus of interest according to claim 22 wherein said purifying is performed by polyethylene glycol precipitation or ultrafiltration.
24. The method of claim 22 or claim 23 wherein the virus of interest is a plus-sense RNA virus.
25. The method of claim 22 or claim 23 wherein said virus of interest is selected from the group consisting of a potyvirus, a tobamovirus, a bromovirus, a carmovirus, a

luteovirus, a marafivirus, the MCDV group, a necrovirus, the PYFV group, a sobemovirus, a tombusvirus, a tymovirus, a capillovirus, a closterovirus, a carlavirus, a potexvirus, a comovirus, a dianthovirus, a fabavirus, a nepovirus, a PEMV, a furovirus, a tobravirus, an AMV, a tenuivirus and a rice necrosis virus.

26. The method of claim 22 or claim 23 wherein said virus of interest is selected from the group consisting of a caulimovirus, a geminivirus, a reovirus, the commelina yellow mottle virus group and a cryptovirus.

27. The method of claim 22 or claim 23 wherein said virus of interest is selected from a Rhabovirus and a Bunyavirus.

28. A method for obtaining a fusion peptide or fusion protein of interest from a plant comprising the steps of:

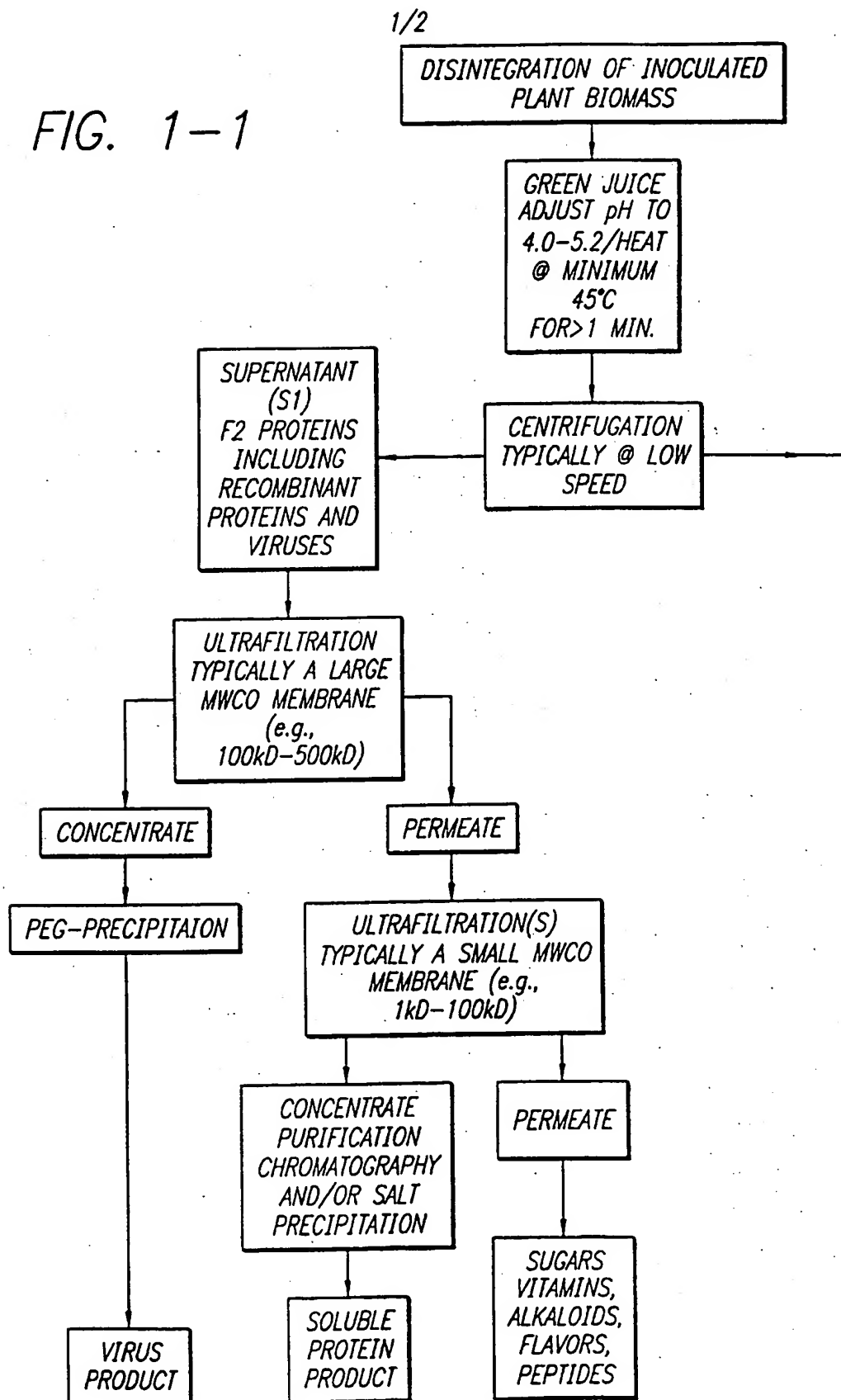
- (a) homogenizing a plant to produce a green juice;
- (b) adjusting the pH of the green juice to less than or equal to about 5.2;
- (c) heating the green juice to a minimum temperature of about 45 °C;
- (d) centrifuging the green juice to produce a pellet;
- (e) resuspending the pellet in a liquid solution;
- (f) adjusting the pH of the liquid solution containing the resuspended pellet to about 2.0 to 4.0;
- (g) centrifuging the liquid solution containing the resuspended pellet; and
- (h) purifying the fusion protein or fusion peptide of interest.

29. A method for obtaining a fusion protein or fusion peptide of interest according to claim 28 wherein the purifying is performed by at least one method selected from the group consisting of chromatography, ultrafiltration, affinity-based method of purification, and salt precipitation.

30. The method of claim 28 or claim 29 wherein said fusion protein or fusion peptide comprises a peptide or protein selected from the group consisting of IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, EPO, G-CSF, GM-CSF, hPG-CSF, M-CSF, Factor VIII, Factor IX, tPA, hGH, receptors, receptor antagonists, antibodies, single-chain antibodies, enzymes, neuropeptides, insulin, antigens, vaccines, and calcitonin.

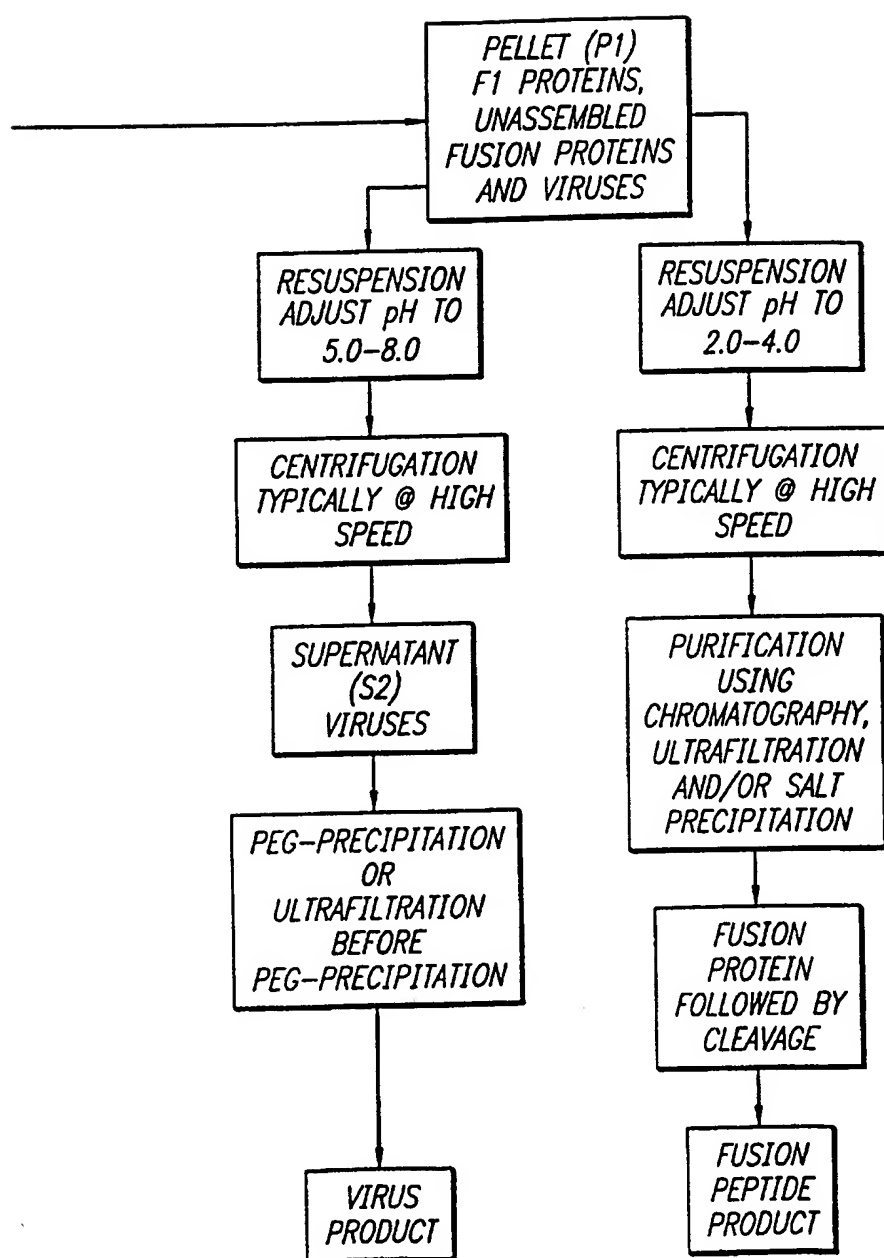
31. The method of claim 28 or claim 29 wherein said fusion protein or fusion peptide comprises an antimicrobial peptide or antimicrobial protein selected from the group consisting of: protegrins, magainins, cecropins, melittins, indolicidins, defensins, β -defensins, cryptidins, clavainins, plant defensins, nicin and batenecins.
32. A method according to claim 5 wherein said ultrafiltration produces a permeate comprising one or more molecules selected from the group consisting of sugars, polysaccharides, vitamins, alkaloids, flavor compounds and peptides.
33. A method according to claim 6 wherein said second ultrafiltration produces in a permeate containing molecules selected from the group consisting of sugars, polysaccharides, vitamins, alkaloids, flavor compounds and peptides.
34. A protein or peptide obtained according to the method of claim 1.
35. A virus obtained according to the method of claim 12 or claim 22.
36. A fusion protein or fusion peptide obtained according to the method of claim 28.
37. A sugar, polysaccharide, vitamin, alkaloid, flavor compound or peptide obtained according to the method of claim 32 or claim 33.
38. A method for obtaining a green juice from a plant comprising the steps of:
(a) homogenizing a plant to produce a liquid solution;
(b) adjusting the pH of the liquid solution to less than or equal to about 5.2.
39. A green juice comprising one or more molecules selected from the group consisting of a virus, a protein and a peptide produced by:
(a) homogenizing a plant to produce a green juice;
(b) adjusting the pH of the green juice to less than or equal to about 5.2.

FIG. 1-1



2/2

FIG. 1-2



1
SEQUENCE LISTING

(1) GENERAL INFORMATION

- (i) APPLICANT: GARGER, STEPHEN
HOLTZ, R. BARRY
McCULLOCH, MICHAEL
TURPEN, THOMAS
- (ii) TITLE OF THE INVENTION: A PROCESS FOR ISOLATING AND
PURIFYING VIRUSES SOLUBLE PROTEINS AND PEPTIDES
FROM PLANT SOURCES
- (iii) NUMBER OF SEQUENCES: 5
- (iv) CORRESPONDENCE ADDRESS:
 - (A) ADDRESSEE: Howrey & Simon
 - (B) STREET: 1299 Pennsylvania Avenue N.W.
 - (C) CITY: Washington
 - (D) STATE: DC
 - (E) COUNTRY: USA
 - (F) ZIP: 20004
- (v) COMPUTER READABLE FORM:
 - (A) MEDIUM TYPE: Diskette
 - (B) COMPUTER: IBM Compatible
 - (C) OPERATING SYSTEM: DOS
 - (D) SOFTWARE: FastSEQ for Windows Version 2.0
- (vi) CURRENT APPLICATION DATA:
 - (A) APPLICATION NUMBER:
 - (B) FILING DATE: 10-MAR-1998
 - (C) CLASSIFICATION:
- (vii) PRIOR APPLICATION DATA:
 - (A) APPLICATION NUMBER:
 - (B) FILING DATE:
- (viii) ATTORNEY/AGENT INFORMATION:
 - (A) NAME: Halluin, Albert P
 - (B) REGISTRATION NUMBER: 25,277
 - (C) REFERENCE/DOCKET NUMBER: 00801.0140.999
- (ix) TELECOMMUNICATION INFORMATION:
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 - (B) TELEFAX: 650-463-8400
 - (C) TELEX:

(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 6395 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: unknown
- (ii) MOLECULE TYPE: Genomic RNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

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180
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4980
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 6300
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 6360
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 6395

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 6439 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: Genomic RNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

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 120
 GAAACAACUC CUUGGUCAAU GAUCUAGCAA AGCGUCGUCU UUACGACACA GCGGUUGAAG
 180
 AGUUUAACGC UCGUGACCGC AGGCCCAAGG UGAACUUUUC AAAAGUAAUA AGCGAGGAGC
 240
 AGACGCUUUA UGCUACCCGG GCGUAUCCAG AAUUCCAAU UACAUUUUAU AACACGCAAA
 300
 AUGCCGUGCA UUCGCUUGCA GGUGGAUUGC GAUCUUUAGA ACUGGAAUUA CUGAUGAUGC
 360

AAAUUCCCUA CGGAUCAUUG ACUUAUGACA UAGGCGGGAA UUUUGCAUCG CAUCUGUUCA
420
AGGGACGAGC AUAUGUACAC UGCUGCAUGC CCAACCUGGA CGUUCGAGAC AUCAUGCGGC
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ACGAAGGCCA GAAAGACAGU AUUGAACUUA ACCUUUCUAG GCUAGAGAGA GGGGGGAAAA
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(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 6425 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: Genomic RNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

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4080
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6425

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 6475 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: Genomic RNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

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120
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180
AGUUUAACGC UCGUGACCGC AGGCCCAAGG UGAACUUUUC AAAAGUAAUA AGCGAGGAGC
240
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300
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360
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6360
AUCGAAGGGU UGUGUCUUGG AUCGCGCGGG UCAAAUGUAU AUGGUUCAU UACAUCGCA
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(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 6446 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: Genomic RNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

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180
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240
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420
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